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Biological changes in an alpine river, the Durance, below the Serre-Poncon Dam. Species composition 18 and 25 years after filling the reservoir

B. Dumont

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BIOLOGICAL CHANGES IN AN ALPINE RIVER, THE DURANCE, BELOW THE SERRE-PONCON DAM. SPECIES COMPOSITION 18 AND 25 YEARS AFTER FILLING OF THE RESERVOIR.

DUMONT, B

Centre national du machinisme agricole,
du génie rural, des eaux et des forêts.

CEMAGREF - Le Tholonet
BP 99 13603 AIX-en-PROVENCE
FRANCE

INTRODUCTION

Since the 1970's, the body of knowledge on biological changes below large dams has grown considerably.

Most authors in this field appear in a large number of North American and English publications. Those who have specialized in benthic fauna include W D Pearson (1968), D S Radford and R Hortland-Rowe (1971), J A Spence and H B N Hynes (1971), D M Lehmkuhl (1972), H M Trotsky and R W Gregory (1974), J A Gore (1977), P D Armitage (1978) E D Evans (1979), J Scullion et al (1982), J Scullion and A Sinton (1983) and, of course,

J W Ward (1976 a, b), who reviewed the main biological effects below large dams, and who initiated, with J A Stanford, the first symposium on regulated streams (FISORS).

Only a few French researchers have published in this area. These include H Decamps et al (1979), who contributed to FISORS, C Berthelemy and C Laur (1975), who reported the disappearance of most plectopterans below dams on the Lot River, and O Gaschignard and A Berly, who participated in the third symposium.

The lack of biological data on sites below large French dams undoubtedly derives from the fact that these dams were built at a time of indifference to environmental protection. It has been only since 1976, under the Loi de protection de la nature [environmental protection act], that impact studies have been obligatory for all land use projects. While concepts related to the aquatic environment have been defined for hydrobiological impact studies (such as the annual cycle and migration phenomena in fish), the form of these studies remains unclear.

Furthermore, those studies are paid for, and remain the property of, their petitioners, which helps explain the lack of literature in this area. Most of the available literature consists of university theses (A Gregoire, 1981)

and studies financed by the Ministère de l'Environnement [department of the environment] such as the scientific report of the Université de Provence on hydroelectric reservoirs of the Verdon River (Champeau, 1981), and the studies of the Durance River which provide the data for this paper.

The purpose of this text is to assess biological changes below France's largest dam, Serre-Ponçon, based on two studies conducted 7 years apart.

CHARACTERISTICS OF THE DAM

The Serre-Ponçon development was built between 1955 and 1961; filling of the reservoir started in November 1959.

The dam is 123 m high and is located on an Alpine torrent in the South-East of France, the Durance River, downstream of the confluence with the Ubaye river (Fig 1).

Its storage capacity is 1.27×10^{12} m^3, of which 1×10^{12} m^3 is usable.

The reservoir is approximately 20 km long. The watershed has an area of 3600 km^2 and an average elevation of 2020 m.

Table 1 gives the monthly flows (m^3/s) from 1960 to

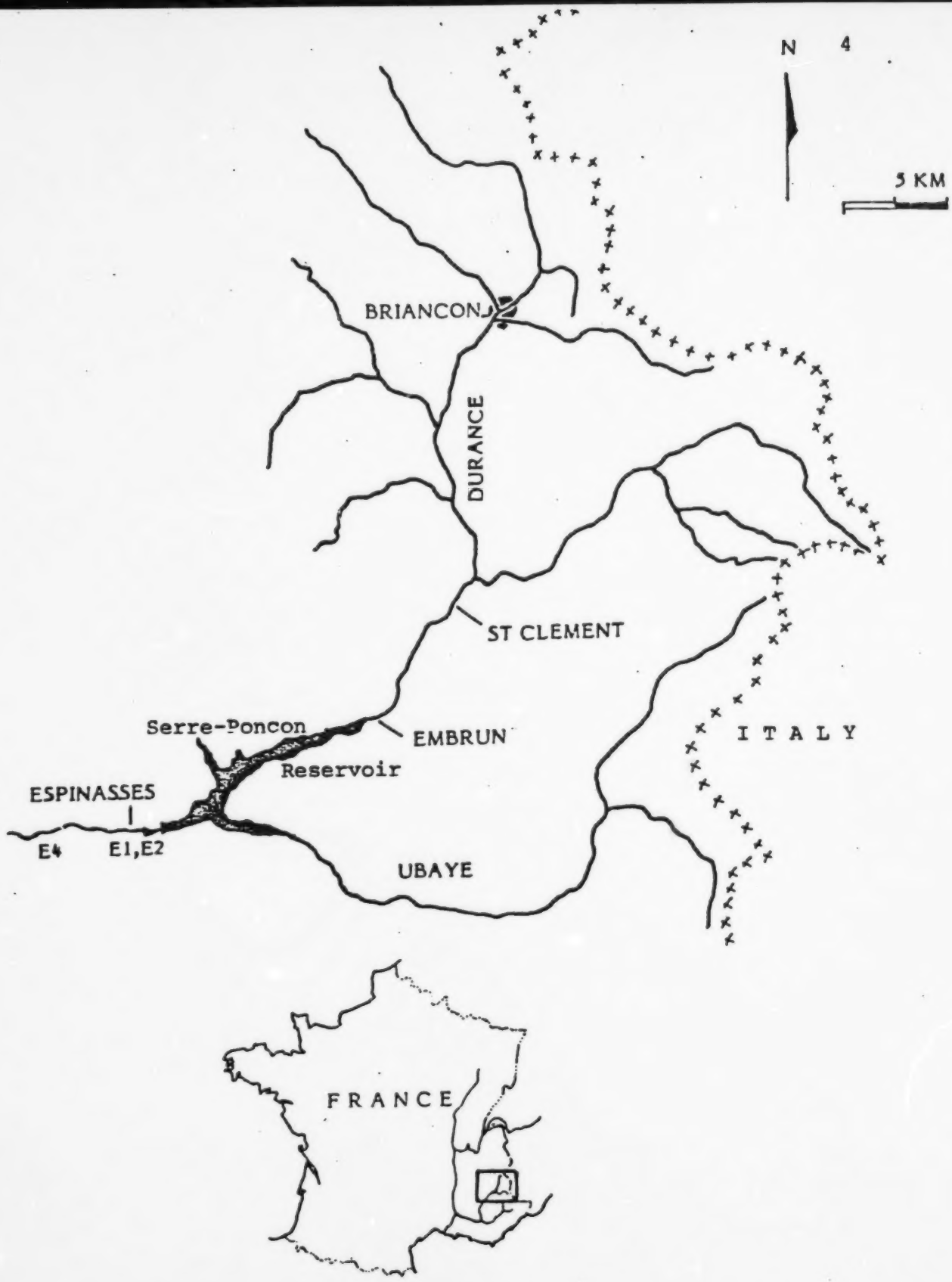


Fig 1. Location of sampling stations

1982. The maximum and minimum observed flows were 1,800 m^3/s and 18 m^3/s respectively. The average yearly flow is 83.3 m^3/s.

A compensation reservoir located at the toe of the dam receives the water discharged from the turbines (300 m^3/s maximum). Its capacity is 6 million m^3 and it feeds a canal, opened in 1966, that diverts water from the river to the rest of the course.

Table 1: Monthly flows (m^3/s) for 1960 - 1982.
EDF data.

January	32.6	July	124.0
February	33.9	August	68.9
March	42.7	September	60.7
April	79.2	October	66.5
May	175.0	November	58.0
June	216.0	December	37.9

Consequently, all flow downstream of the Serre-Ponçon dam (for 215 km) is regulated. The course is divided into 6 sections of different lengths by 5 dams that have no role in water storage but which act as relays to ensure constant flow through the power canal. These dams also allow recovery of water from intermediate watersheds.

The legal compensation flow is fixed at 1.5 m^3/s downstream from the compensation reservoir. Nevertheless, flow here has not been constant since the opening of the diversion canal. Higher flows from the Durance were recorded downstream of the compensation reservoir up to 1975. Water was released for summer irrigation, and the legal compensation flow was in effect only during the cold season (fall and winter). These observations were made by an informed fisherman who witnessed this transition period and who fought to defend this section after noticing the rapid deterioration of the river's salmon fishery (Fleckinger, 1984).

Indeed, daily flows in the Durance River diversion have not been recorded since 1960. Peak discharge values, however, are known. These discharges occurred for the first time in 1977 when the reservoir flooded during the snow-melt. Discharges exceeded 100 m^3/s in May, June, and July 1977 and reached 265 m^3/s. Similarly, in July 1978, a maximum of 110 m^3/s was recorded.

TIME-FRAME OF THE STUDY

We started work on the Serre-Ponçon site in September 1977.

To the best of our knowledge, no scientific data on the biology of the site had been collected prior to a

methodological study on compensation flows which was started at this time. This study dealt primarily with high- and medium-head hydroelectric schemes upstream of Serre-Ponçon. The schemes, designated as non-storage diversions, are all of the same type and are located on the Durance River and its tributaries. We included the Serre-Ponçon development in our study.

Twenty-one sites in the watershed were studied over a two-year period up to October 1979. Five hundred and seventy samples were analysed with respect to density (by number and by weight) and diversity.

Part of the data in this paper dates from this period; the remainder is provided by a new study started in October 1984. This study is part of a program for evaluating compensation flows in France and involves the 20 km first section of the Durance River, downstream of the compensation reservoir.

The compensation flow problem has been misunderstood in this case, and the study's purpose is to assess the biological effects of increasing the flow. This increase will soon be limited, since Electricité de France (EDF), which owns the Durance development, believes it is entitled to ask for financial compensation for any additional discharges into the compensation reservoir.

Our strategy for this study is based on (1) determining the present biotic state, (2) identifying the factors which led to this state, and (3) describing the morphodynamics of the bed and the nature of the sediments.

The synthesis of this data will allow us to evaluate the likely physical and biological changes associated with a realistic range of flows.

The results which follow deal mainly with benthic invertebrates; the semi-quantitative presentation of the data is intentional, although our methods allow a different type of analysis (see Material and Methods). This is also part of another aspect of the methodology, aimed at testing an aquatic environment and providing initial results promptly through quick assessment.

CHARACTERISTICS OF THE STUDY SITE

The Embrun sampling site is located upstream of the reservoir, at an elevation of 795 m. The average slope is approximately 0.6 per cent. The average width is 40 m. The annual temperature range is in the area of 1 to 15^{o}C and the conductivity ranges between 400 and 600 micro-Siemens. The river belongs to the first category of fishery.

The Espinasses study station, which is downstream of the reservoir, ranges in elevation from 600 to 650 m. It is 36 km from the upstream station. Its average slope is approximately 0.4 per cent and its average width is 20 m. The maximum temperature range observed was 2 - 22°C, between October 1977 and July 1979, at the Rochebrune Bridge, 3 km downstream from the compensation reservoir. The conductivity ranged between 150 and 300 micro-Siemens at the outlet of the compensation reservoir.

From 1977 to 1979, samples were taken from the compensation flow 1.5 km from the point where the water is returned. Since October 1984, several sites have been studied. The results from three of these are given here.

Two sites are located 300 m downstream of the compensation reservoir (Espinasses 1 = E1 and Espinasses 2= E2). The third is 9 km downstream (Espinasses 4 = E4). The first two stations differ with respect to the level of alluvial deposits present. At this point, the Durance divides into two branches, one (E2) receives alluvium-rich water from an intermittent torrent, the Trente Pas Torrent, while the other (E1) receives only very small amounts of this water.

Indeed, alluvial deposits are an important characteristic of the wetted bed of this section. At Serre-Ponçon

and further downstream, the Durance crosses through schist and marly limestone. The erosion products of these leach easily and move readily through the wetted bed when it rains.

Station E4 is located in a section where gravel removal has greatly modified bed morphology and the nature of the stony substratum. Significant heating of the water was observed. For example, in May 1985, we recorded 9.8°C at E1 at 4:30 pm and 14.5°C at E4 at 6:00 pm. Stations E1 to E4 belong to the first category of fishery, whose lower limit is near E4.

MATERIALS AND METHODS

Benthic fauna were sampled in running water by means of a Surber net with a surface area of 0.1 m^2 and a mesh size of 250 µm.

Between 1977 and 1979, comparisons (upstream and downstream of the reservoir) were based on the examination of 6 samples per campaign. Eight campaigns were conducted between periods of peak flows (Fig 2).

Since 1984, two campaigns have been conducted downstream of the dam, one in October 1984, the other in May 1985. Ten samples per campaign were collected from each of the stations immediately downstream of the compensation

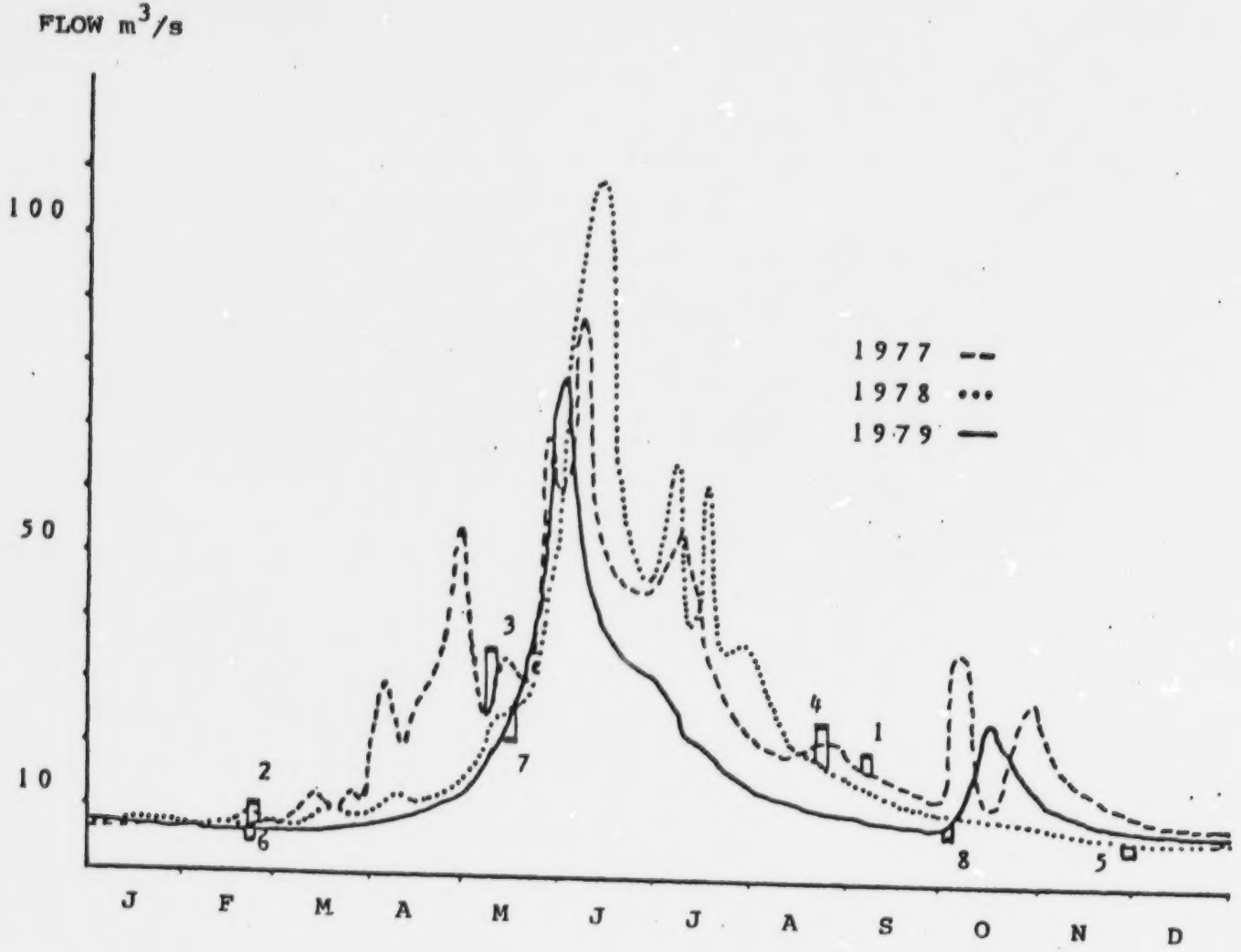


Fig 2. Hydrologic cycles (daily flows downstream of Briançon. EDF data) and sampling campaigns.

reservoir, while a total of 13 samples were collected from E4.

Each sample was identified according to its position in the river, the flow velocity (average velocity of the first 30 cm of water above the substratum), particle size, and type of surface vegetation.

For the two study periods, the benthic fauna were compared by means of the frequency of appearance of taxa (a taxon = a species, a genus, a tribe, a family, etc, depending on the degree of identification that was possible). For the second study period, the data on the taxa were analysed with reference to the physical characteristics of their location in the wetted bed.

Inter-station, inter-specific or intra-specific differences were evaluated by standard statistical tests: the chi-square test, the Mann-Witney test or the t test depending on the form of the data (Snedecor and Cochran, 1971--French translation).

BENTHIC POPULATIONS

1977 - 1979 Period

Overall assessment

Figure 3 shows the frequency of appearance of taxa in samples for three faunal groups (Plecoptera, Trichoptera, and Ephemeroptera) over the eight campaigns.

Plecoptera: The upstream station accounted for 85.7% of the total number of taxa found. The percentage of common taxa was 42.9%.

Tricoptera: Each station accounted for 60% of the total number of taxa, but only 20% of the taxa were common.

Ephemeroptera: This group showed the greatest diversity. Eighteen taxa were identified, of which 88.9% were found at the downstream station. This was also the order with the highest percentage of common taxa (50%).

For the three orders, the percentage of the total number of taxa found in each station was approximately the same: 69% for the upstream station, and 71.4% for the downstream. They differ significantly, however, in that the percentage of common taxa was only 40.5%.

Figure 4 shows the frequency of appearance for the remaining benthic fauna.

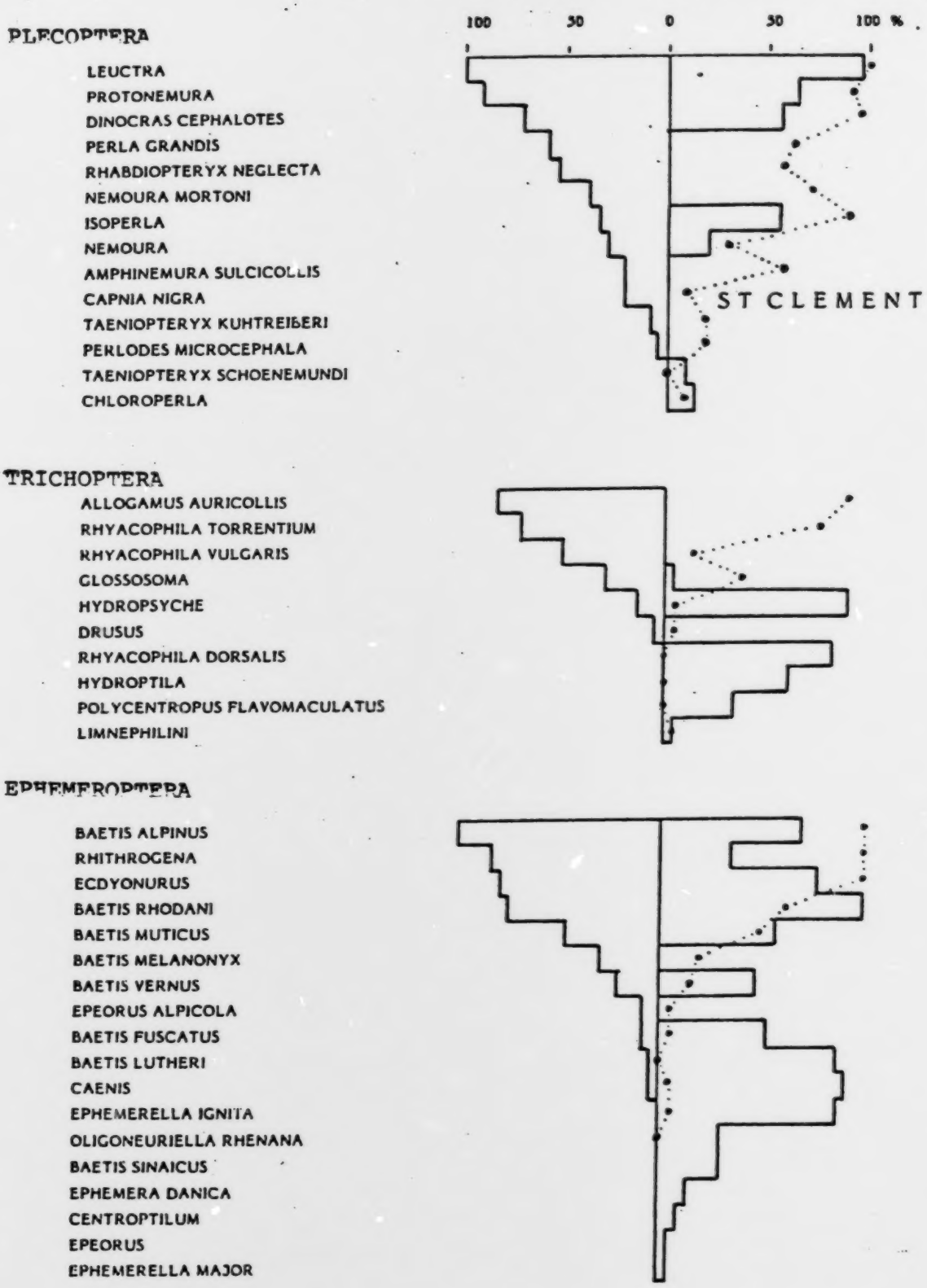


Fig 3. Frequency of appearance of taxa for all campaigns from 1977 to 1979.

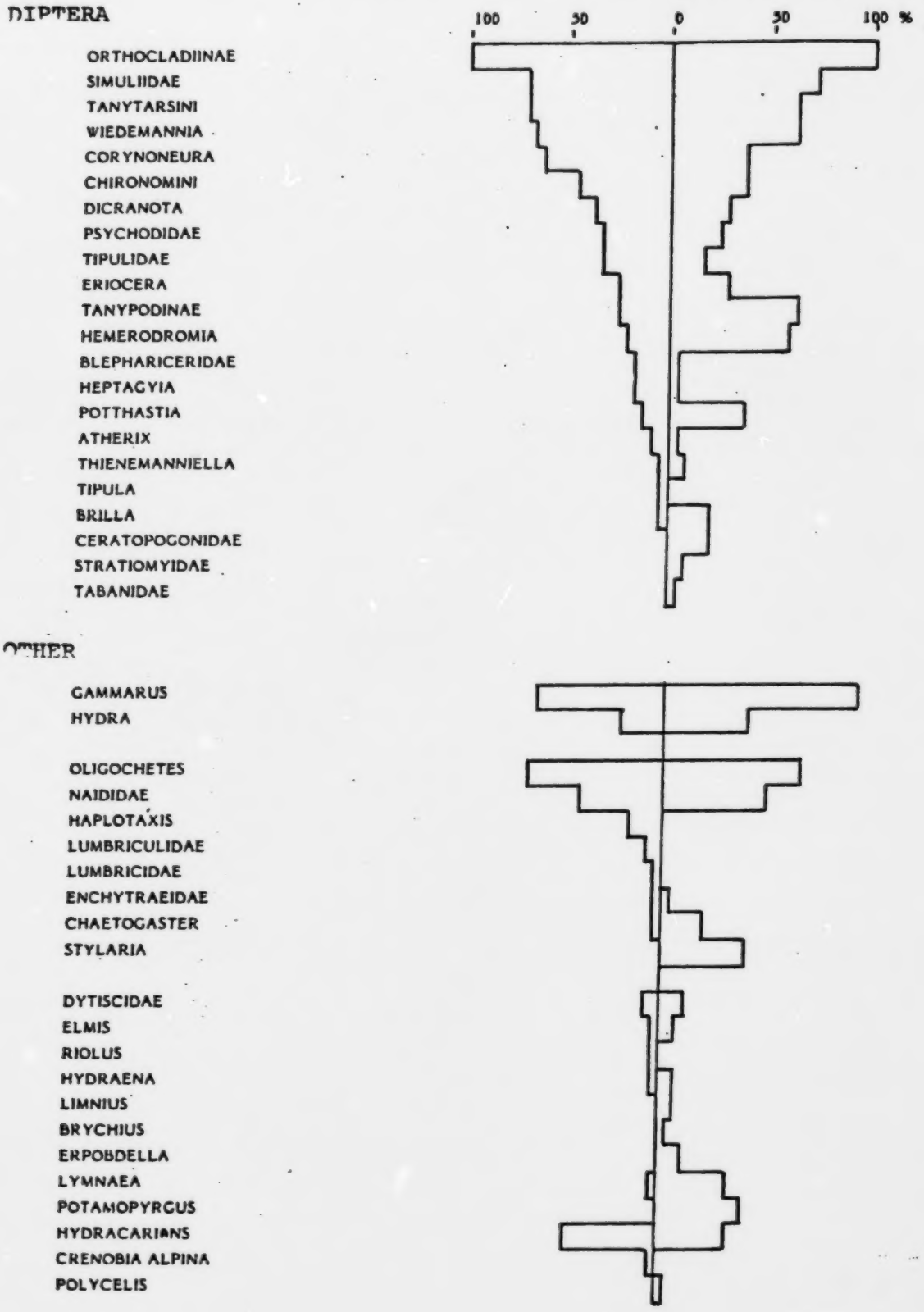


Fig 4. Frequency of appearance of taxa for all the 1977 - 1979 campaigns.

The number of common taxa was high for the Diptera (81.8%), but the degree of taxonomic identification was the lowest.

For the Coleoptera, Crustaceans, Planarians, Hirudinea, Molluscs, Oligochaetes and Hydracarians, the percentage of taxa common to both stations was 50%.

For all the communities, the percentage of common taxa was 53.5%.

Differences in the frequencies of taxa in Plecoptera, Trichoptera and Ephemeroptera were found to be highly significant by the chi-square test ($P < 0.01$).

For the Diptera, no difference was found at the 5% significance level using the chi-square test, although the value was very close.

For the rest of the fauna, the test showed a highly significant difference ($P < 0.01$).

For comparative purposes, the same procedure was used with data from Embrun and St Clément, a station further up the Durance River, to give the following results: Plecoptera, 92.3% common taxa: Trichoptera, 85.7% common taxa; and Ephemeroptera, 83.3% common taxa.

No significant difference was found at the 5% level in the frequencies of appearance of taxa within each faunal group. Figure 3 summarizes the comparison between Embrun and St Clément.

The difference in benthic populations upstream and downstream of the reservoir appears unusually pronounced, and Table 2 presents the species particular to each station. Identifications of adult insects are included in this table.

Table 2: 1977 - 1979 Study Period
Species particular to the Embrun and Espinasses stations

	Embrun	Espinasses
Plecoptera	Perla grandis	Taeniopteryx schoenemundi
	Rabdiopteryx neglecta	Leuctra fusca
	Taeniopteryx kühtreiberi	Leuctra major
	Nemoura mortoni	
	Capnia nigra	
	Leuctra inermis	
	Perlodes microcephala	
	Rhyacophila torrentium	Rh. dorsalis
	Rh. vulgaris	Hydropsyche siltalai
		Hydroptila forcipata
		Hydroptila vectis
		Agraylea sexmaculata
		Polycentropus flavomaculatus
		Sericostoma galeatum
Ephemeroptera	Epeorus alpicola	Epeorus sp.
	B. melanonyx	B. sinaicus
		Centroptilum sp.
		Ephemerella ignita
		Ephemerella major
		Oligoneuriella rhenana
		Ephemera danica
		Caenis sp.

The quantitative data, expressed as captures according to density by number and by weight, also indicate that significant biocenotic differences presently exist between sites upstream and sites downstream of the Serre-Ponçon reservoir (Dumont and Rivier, 1980).

Seasonal results

Figure 5 shows the variation in the number of taxa captured per campaign. The seasonal data confirm the trend found in the overall results, and there are very significant inter-station differences between the Plecoptera and Ephemeroptera populations. Plecoptera diversity was still higher at the upstream station than at the downstream station. The opposite was true for Ephemeroptera diversity.

Use of the t test shows a highly significant difference in the average number of captured taxa ($P < 0.01$) for Plecoptera and Ephemeroptera, while at the 5% level no difference was found for Trichoptera.

Table 3 indicates the presence or absence of taxa for each campaign. Some taxa appear throughout the year. At the upstream station, these are Leuctra, Protonemura, Dinocras cephalotes, Perla grandis, Allogamus auricollis, Rhyacophila torrentium, Baetis alpinus, Rhithrogena; for the downstream station, these are Leuctra, Hydropsyche pellucidula, Rhyacophila dorsalis, Baetis alpinus, Baetis

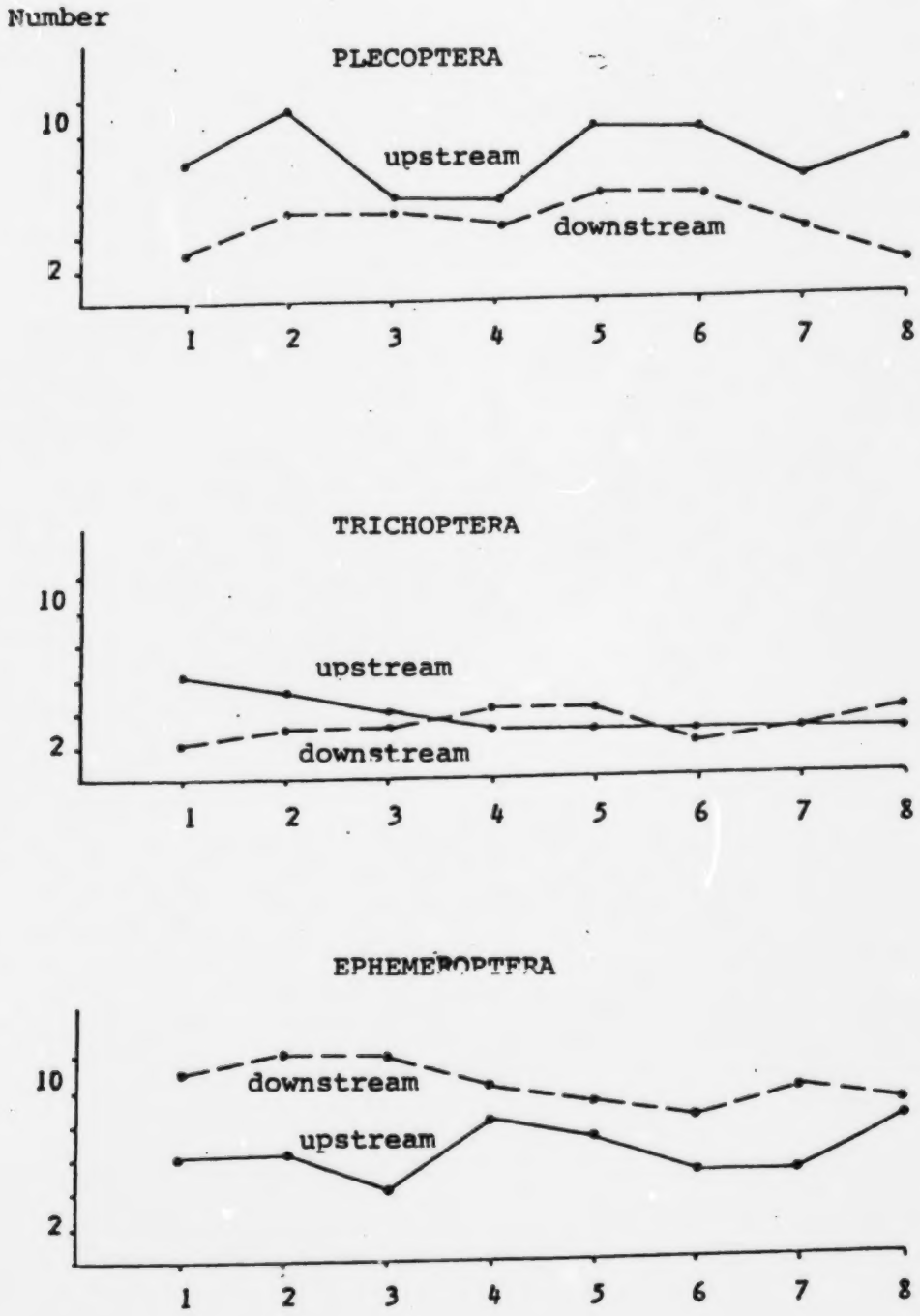
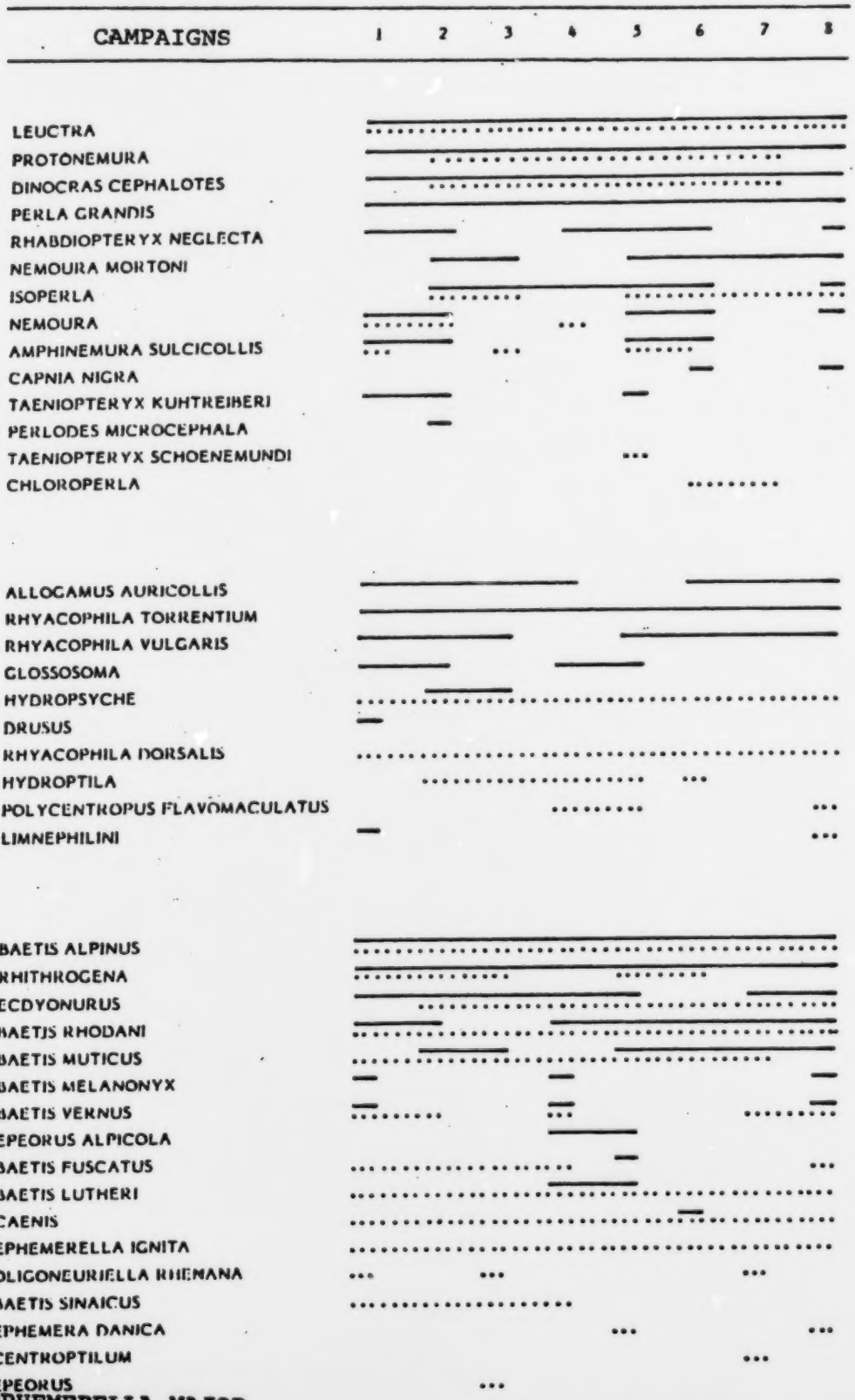


Fig 5. Variation in faunal diversity over eight sampling campaigns.

Table 3: 1977 - 1979 Period. Seasonal data for fauna upstream (———) and downstream (.....) of Serre-Ponçon. 1, 09-77; 2, 02-78: 3, 05-78; 4, 08-78; 5, 11-78; 6, 02-79; 7, 05-79; 8, 10-79.



rhodani, Baetis lutheri and Caenis.

Others appear irregularly. Their presence sometimes is linked to the length of their aquatic cycle. Such species include those with winter larval growth like Rhabdiopteryx neglecta, Capnia nigra, Taeniopteryx kühtreiberi, or species with summer larval growth like Baetis melanonyx, Baetis vernus, Baetis sinaicus, and Ephemerella ignita.

Finally, others appear sporadically. Sometimes this indicates the limit of their longitudinal distribution in the river. This, however, can only be confirmed by determining the biocenotic composition upstream and downstream of the site under study. This was the case for the station upstream of the dam, where the species T. kühtreiberi, P. microcephala and E. alpicola were at the lower limit of their distribution, while H. pellucidula, Baetis lutheri, Baetis fuscatus, and Caenis sp. were at their upper limit.

Since there are no data on biocenotic composition downstream of the study site, our assessment of the river below Serre-Ponçon is limited to an enumeration of the species particular to the station.

A seasonal characteristic of this sampling period was the disappearance of the ephemeropteran Baetis sinaicus below Serre-Ponçon during the last four campaigns. Moreover,

its presence in the previous four campaigns was just as unexpected, since this ephemeropteran is typically a summer species, its larval development taking place from spring to fall. In the Upper Verdon, it has been found as high as 1200 m (Dumont et al, 1978). It is found in stations at lower altitudes, in the Buech River (Vespini, 1985) and in the Asse River (Prevot, 1984). These three rivers are tributaries of the Durance, downstream of the Serre-Ponçon site.

It is difficult to explain the winter presence of this Baetid species downstream of Serre-Ponçon and its disappearance the following year. It is possible that these Baetidae were a relic population which had survived to this point and which disappeared in the transition phase between 1975 and 1977, when the compensation flow was maintained throughout the year and when the first major discharges occurred. The new study that is being conducted in this section should provide further information, and the presence of B. sinaicus in the Ubaye River should be confirmed.

1984 - 1985 Period: Biotic state below the dam

Table 4 presents the faunal composition at each station during each campaign. The sets of invertebrates from both E1 and E2 were used to compare this study period with the previous one, since these stations are close to the 1977 study site.

Table 4: October 1984 and May 1985 faunal composition downstream of the Serre-Ponçon dam.

	OCTOBER 84			MAY 85		
STATIONS	E1	E2	E4	E1	E2	E4
DINOCRAS CEPHALOTES	———	———	———	———	———	———
LEUCTRA	———	———	———	———	———	———
PROTONEMURA				———	———	———
NEMOURA	———	———	———			
AMPHINEMURA SULCICOLLIS	—		—			
PERLA MARGINATA		———	———			
TAENIOPTERYX SCHOENEMUNDI		—				—
BRACHYPTERA					—	
CHLOROPERLA					—	
ISOPERLA						—
RHYACOPHILA DORSALIS	———	———	———	———	———	———
HYDROPTILA	———	———	———	———	———	———
HYDROPSYCHE	———	———	———	———	———	———
SERICOSTOMA GALEATUM	———	———	———	———	———	
AGAPETUS CRAVENSIS	———	———	———	———	———	———
POLYCENTROPUS FLAVOMACULATUS	—			—	—	
SILO NIGRICORNIS				—		
PSYCHOMYIA PUSILLA	—		—	———	———	———
LIMNEPHILINI				———	———	———
CHAETOPTERYGINI				—		
GLOSSOSOMA		———	———			
TINODES					———	———
SETODES					———	———
CHEUMATOPSYCHE LEPIDA			—			—
BAETIS RHODANI	———	———	———	———	———	———
CAENIS	———	———	———	———	———	———
EPHEMERELLA IGNITA	———			———	———	———
BAETIS LUTHERI	———	———	———	———	———	———
ECDYONURUS	———	———	———	———	———	———
EPHEMERA DANICA	———	———	———	———	———	———
PARALEPTOPHLEBIA	—			—		
BAETIS MUTICUS	———	———	———	———	———	———
RHITHROGENA	———	———		———	———	
BAETIS ALPINUS	———	———	———	———	———	
BAETIS FUSCATUS	———	———	———			—
CENTROPTILUM		—		—		—
HEPTAGENIA				———	———	———
OLIGONEURIELLA RHENANA					———	———
BAETIS VERNUS		—			———	———
EPHEMERELLA MAJOR			—			—
POTAMANTHUS LUTEUS						—

Ten new species were collected: two of Plecoptera, Perla marginata and Brachyptera sp.; five of Trichoptera, Agapetus cravensis, Psychomyia pusilla, Tinodes sp., Silo nigricornis and Setodes sp.; two of Ephemeroptera, Heptagenia sp. and Paraleptophlebia sp.; and one of Hirudinea, Piscicola geometra.

The appearance of these species indicates changes in the community caused by populations that originated from the downstream portion of the watershed. This trend was confirmed by the species composition of station E4, which included the tricopteran, Cheumatopsyche lepida, the Ephemeropteran, Potamanthus luteus, larvae of a gyrinid coleopteran, and the odonates, Calopteryx sp. and Gomphus sp. The community downstream from the compensation reservoir was much more affected by populations from the lower Durance in 1985 than it was in 1978. It is also apparent that longitudinal zonation of biota has occurred in the first by-passed reach. Study of sites upstream and downstream of station E4 will allow us to elucidate this phenomenon, which is largely associated with heating of water at the source. The situation, however, is complicated by other major occurrences, alluvium extraction and urban pollution.

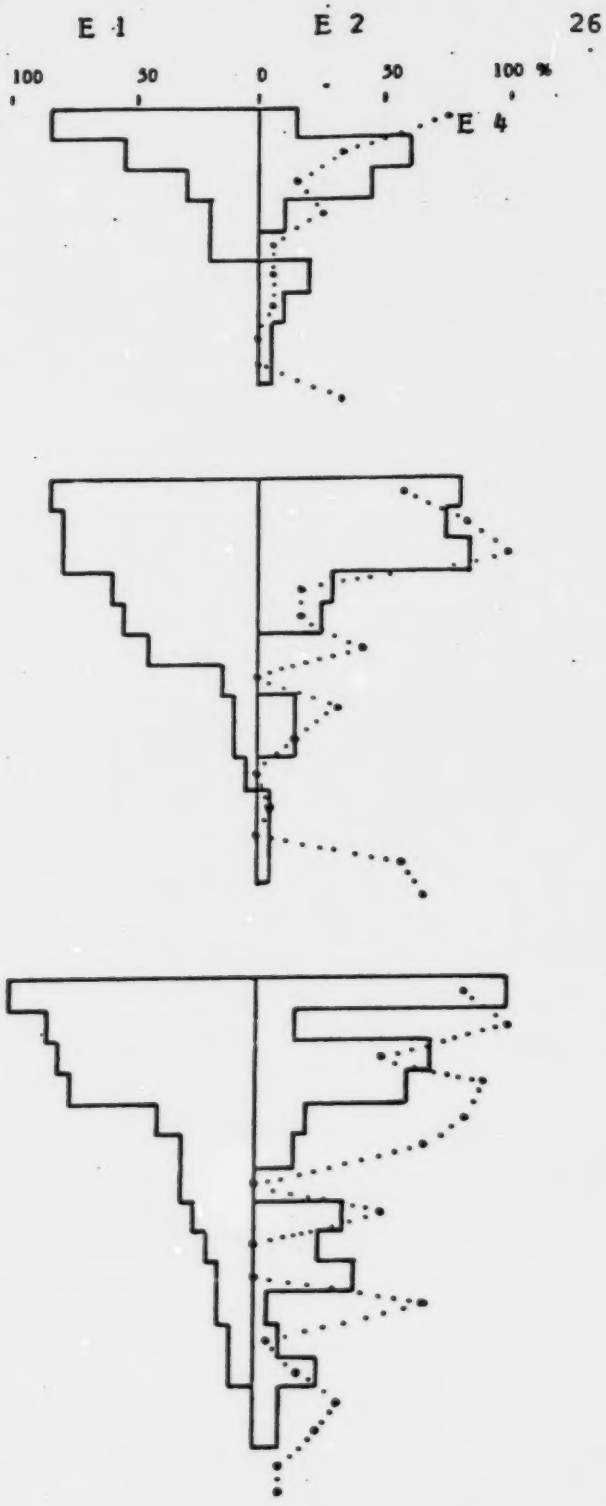
In addition to biological assessment, another aspect of the 1984 - 1985 study is how silting of the stony

substratum affects species. Indeed, at the compensation flow level, the river no longer has the solid-carrying capacity needed to remove most of the alluvium acquired laterally when it rains. Considerable sedimentation of the substratum occurs, and interstitial silting of the wetted bed becomes widespread. A possible restoration of the aquatic habitat would also involve evaluating the potential for silt removal under conditions of increased flow velocity. This fact is especially important if the salmon fishery is to be improved from its present state.

It is for this purpose that stations E1 and E2 were studied. Figure 6 shows this comparison for both the October and May campaigns.

The species missing from the two campaigns in the station most affected by silting are a trichopteran, Polycentropus flavomaculatus and an ephemeropteran, Paraleptophlebia sp. The larval form of the first, a caseless, carnivorous trichopteran, spins very flexible nets in still or slow-moving water (9 - 45 cm/s at E1). The larval form of the second feeds by scraping the substratum; it was collected in water moving at velocities of 21 - 60 cm/s.

The most significant differences were observed in the case of Dinocras cephalotes. The large larva of this plecopteran of the Perlidae family is a carnivore which



PLECOPTERA

- DINOCRAS CEPHALOTES
- LEUCTRA
- PROTONEMURA
- NEMOURA
- AMPHINEMURA SULCICOLLIS
- PERLA MARGINATA
- TAENIOPTERYX SCHOENEMUNDI
- BRACHYPTERA
- CHLOROPERLA
- ISOPERLA

TRICHOPTERA

- RHYACOPHILA DORSALIS
- HYDROPTILA
- HYDROPSYCHE
- SERICOSTOMA GALEATUM
- AGAPETUS CRAVENSIS
- POLYCENTROPUS FLAVOMACULATUS
- SILO NIGRICORNIS
- PSYCHOMYIA PUSILLA
- LIMNEPHILINI
- CHAETOPTERYGINI
- GLOSSOSOMA
- TINODES
- SETODES
- CHEUMATOPSYCHE LEPIDA

EPHEMEROPTERA

- BAETIS RHODANI
- CAENIS
- EPHEMERELLA IGNITA
- BAETIS LUTHERI
- ECDYONURUS
- EPHEMERA DANICA
- PARALEPTOPHLEBIA
- BAETIS MUTICUS
- RHITHROGENA
- BAETIS ALPINUS
- BAETIS FUSCATUS
- CENTROPTILUM
- HEPTAGENIA
- OLIGONEURIELLA RHENANA
- BAETIS VERNUS
- EPHEMERELLA MAJOR
- POTAMANTHUS LUTEUS

Fig 6. Frequency of appearance of taxa at the Espinasses stations (E1, E2, and E4) for the October 1984 and May 1985 campaigns.

prefers stony substrata and which is greatly limited by silting of the stones. This species was observed at E1 at a relative occurrence of 85% over the entire range of flow velocities examined (9 - 77 cm/s). At E2 it was found with a relative occurrence of 15% over a range of flow velocities of 47 - 110 cm/s. The difference in average values is highly significant for both campaigns taken together.

The stone-cased larva of Sericostoma galeatum, trichopteran of the Sericostomatidae family, appeared at E1 at a frequency of 60%, while at E2 the frequency was only 30%. There was no significant difference between the ranges of flow velocity at the sites where these larvae were captured.

The stone-cased larva of Agapetus cravensis, a trichopteran of the Glossosomatidae family, was observed at E1 at a frequency of 55%, while at E2 the frequency stood at 25%. There was a slight difference in the ranges of flow velocity at the sites where this species was captured: 9 - 77 cm/s at E1 and 42 - 73 cm/s at E2. For both campaigns together, the difference in average velocities is significant at the 5% level.

Caenis sp., an ephemeropteran of the Caenidae family, appeared in greatly reduced numbers at E1 as was the case for Dinocras. The frequency at E1 was 15% compared with

85% at E2. The larvae at E1 were collected in water flowing between 9 and 77 cm/s, while at E2 they were found between 45 and 73 cm/s. There is a significant difference at the 5% level between the average velocities.

Ecdyonurus sp., an ephemeropteran of the Heptageniidae family, appeared two times less frequently at E2. The ranges of average flow velocity at the sites where this species occurred differed significantly at the 1% level. The range at the E1 station was 21 - 55 cm/s, and at the E2 station, 47 - 73 cm/s.

After confirming that there is no significant difference between E1 and E2 with respect to the ranges of flow velocities measured over both campaigns, these few examples indicate that at the initial stage of a qualitative evaluation, very pronounced differences are found in the frequency of occurrence of species, and that sometimes further differences are found in the nature of the colonized habitats. Species leave the more silty habitats in favour of less silty habitats, thereby choosing faster-flowing water.

At the E1 and E2 stations, some species occurred in only one campaign. Excepting those species collected only once, these include the following species: Silo nigricornis, which colonized the E1 station in May 1985 in low-velocity areas only (9 - 33 cm/s); and Taeniopteryx

schoenemundi and Perla marginata which colonized only the E2 station in October 1984. The latter two species colonized faster-flowing water, 60 - 73 cm/s for Taeniopteryx schoenemundi, and 42 - 73 cm/s (averaging 57 cm/s) for Perla marginata. These two species may have been absent from E1 because the velocities measured at E1 varied more than those at E2 (the maximum range at E1 was 21 - 55 cm/s, while at E2 it was 10 - 73 cm/s, although there was no significant difference between the average velocities at the two sites). This explanation was confirmed by the fact that during this period, the average flow velocity where Perla was collected, at all the stations, was 63 cm/s. The total absence of Perla during the May 1985 campaign (including station E4) may be linked to the fact that the individuals collected in 1984 evidently belonged to the same larval cohort, and that major phenomena such as a flood or the exceptional cold in January 1985 (a 15-year cycle) may have contributed to their elimination. Their possible reappearance would be detected only if the study continues.

An observation related to the fishery was made by examining benthic samples from May 1985. Salmo fario alevins with non-absorbed yolk sacs were found in 5 out of 10 habitats at the E1 station. A maximum density of 28 individuals over 0.1 m^2 was recorded. Their presence

is the result of natural reproduction, since the fishery in this section is maintained by means of yearling trout only.

Their absence at the E2 station confirms the especially pronounced oxygen depletion of potential spawning grounds.

CONCLUSION

Between 1977 and 1979 a first examination of benthic populations in running water, upstream and downstream of the Serre-Ponçon reservoir, indicated a marked difference in faunal composition. Most Alpine species disappeared downstream of the dam, but other populations have developed. The difference mainly involved a decrease in Plecoptera diversity and increase in Ephemeroptera diversity, while overall faunal diversities remained similar: 64 taxa upstream and 68 taxa downstream. As Table 5 indicates, replacement occurred within faunal groups.

Primary results from the new study, which started in October 1984 downstream of the dam, indicate that the community has been changed further by the appearance of ten species, whereas since 1978, only one species seems to have disappeared.

Table 5: Faunal composition upstream and downstream of Serre-Ponçon.

	Upstream	Down-stream	Total No.	Common No.
Plecoptera	12	8	14	6
Trichoptera	6	6	10	2
Ephemeroptera	11	16	18	9
Diptera	19	21	22	18
Crustacea	1	1	)	
Coleoptera	4	5	)	
Hirudinea	0	1	)	
Planarians	1	1	) 22	11
Molluscs	1	2	)	
Oligochaetes	7	5	)	
Hydracarians	1	1	)	
Hydras	1	1	)	
T O T A L	64	68	86	46

If the change in the initial ecological state, which has been observed since 1977, resulted from the suppression of faunal exchanges between sites upstream and downstream of the reservoir, the changes observed between 1977 and 1985 below the dam seem linked to the maintaining of the compensation flow throughout the year, which was not the case before 1975 owing to summer releases for irrigation.

The other aspect of the current study is the determination of changes likely to result from increasing the compensation flow. To this end, the following characteristics of the site are taken into account: morphology of the wetted bed, nature and extent of alluvial deposits, heating of the water, growth of aquatic plants, distribution of benthic invertebrates and fish in the wetted bed, cyclic changes, and migratory phenomena of the main species.

With respect to benthic populations, a simple sampling strategy and an initial qualitative analysis allow the determination of the presence and tendencies of different species in different qualities of habitat. Through this type of procedure, it is possible to ascertain the limiting factor(s) that must be alleviated to improve the aquatic situation.

In the case under study, it is highly unlikely that the ecological state that existed before the dam's construction can be restored, or even the state associated with the populations of the Durance and the Ubaye upstream of the reservoir.

It appears, however, that it is more feasible to restore the part of the Durance that belongs to the first category of fishery. An estimate of the required flow supplement could be obtained by combining the biological data with thermal and hydraulic models. It should be noted that the

compensation flow, at approximately 2 m^3/s in the river, is of the order of 1/40 of the yearly flow.